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GUIDELINES FOR THE DESIGN AND CONSTRUCTION OF LOW VOLUME RURAL ROADS USING JUTE GEOTEXTILES

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ABBREVIATIONS

AOS	:	Apparent Opening Size
CRMB	:	Crusher Run Macadam Base
ESAL	:	Equivalent Standard Axle Load
GWT	:	Ground Water Table
IJIRA	:	Indian Jute Industries Research Association
IJMA	:	Indian Jute Mills Association
JGT	:	Jute Geo Textiles
MoRD	:	Ministry of Rural Development
MoRTH	:	Ministry of Road Transport & Highways
NJB	:	National Jute Board
NRIDA	:	National Rural Infrastructure Development Agency
OAR	:	Open Area Ratio
WBM	:	Water Bound Macadam
WMM	:	Wet Mix Macadam

GUIDELINES FOR THE DESIGN AND CONSTRUCTION OF LOW VOLUME RURAL ROADS USING JUTE GEOTEXTILES

1 INTRODUCTION

Geotextiles are textiles embedded in soil to improve its engineering performance. Geotextiles may be either man-made (loosely called synthetic) or natural. Man-made Geotextiles are made of artificial fibres like polypropylene, polyethylene and some other petrochemical derivatives. Natural Geotextiles, on the other hand, are made out of natural fibres like jute, coir, sisal etc. Jute Geotextile (JGT) is a natural Textile. The efficacy of JGT has been established through laboratory studies, extensive successful field applications and research in India and in other parts of the world. It has been observed that JGT, when applied at the interface of sub-grade and sub-base, the load bearing capacity of sub-grade soil is enhanced by the concurrent functions of separation, filtration, drainage and initial reinforcement performed by JGT upto one or two season cycles.

India is the biggest stakeholder of Jute in the world followed by Bangladesh and China. Hence, the use of JGT will increase the utilization of the indigenous-resource within its own geographical area and environment. The National Jute Board (NJB), as Technology Provider of JGT has been conducting promotional activities to create awareness on effectiveness of JGT among the road engineers throughout the country in association with Indian Jute Industries' Research Association (IJIRA) and Indian Jute Mills Association (IJMA). As a result, use of JGT in road construction works has been increasing, though at a very slow pace.

The task of preparation of these Guidelines was taken up by Rural Roads Committee (H-5) during the tenure 2015-17. A subgroup consisting of Dr. U.C. Sahoo (IIT, bhubaneswar), Dr. Praveen Aggarwal (NIT, Kurukshetra), Dr. R.B. Sahu (Jadavpur University), Dr. B.V. Kiran Kumar (GSKSJTI, Bengaluru), Dr. I.K. Pateriya (NRIDA), Dr. U.S. Sarma (IJIRA) and Dr. P.K. Choudhury (NJB) was constituted to prepare the draft. The subgroup submitted its draft to IRC in October, 2017. The draft was discussed in various meetings of H-5 Committee. In the meanwhile, the H-5 Committee was reconstituted for the tenure 2018-20. The draft was again discussed and further modified in the various meetings of H-5 Committee and was approved in its meeting held on 7th May, 2019 for placing before the Highways Specifications and Standards Committee (HSS).

The composition of Rural Roads Committee (H-5) is given below:

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Secretary General, Indian Roads Congress	Nirmal, Sanjay Kumar

The HSS Committee in its meeting held on 20th July, 2019 approved the document for placing before the 218th Mid-Term Council Meeting. The Mid-Term Council in its meeting held on 9th and 10th August, 2019 at Goa requested Convenor, H-5 Committee to modify the document and submit to IRC for placing before Executive Committee. EC was authorized by IRC Council to take a call about approval and publication of this document. Thereafter, the modified document as well as clarifications on issues raised by members of IRC council was placed before the Executive Committee. The Executive Committee in its meeting held on 19.12.2019 at Patna, approved the document for publishing.

2. JUTE AND JUTE GEOTEXTILES

2.1 Jute

Jute is a natural, coarse bast fibre (fibre collected from bast or skin of the plant). The major components of the fibre are Lignin (12-14%), Holocellulose (83-87%), Wax (0.4-0.8%), Ash (0.5-1.0%) and Nitrogen (0.2-0.4%). The strands of jute fibre consist of numerous individual filaments which form a meshy structure. These fibres have varying length, fineness, strength, extensibility, tenacity, stiffness and toughness. Extensibility of jute varies within a short range, which increases when it is wet or moist. Tenacity of jute is usually high and remains stable over a range of 30%-80% of relative humidity. Under very wet or very dry conditions, tenacity of jute decreases. Stiffness of jute is high at normal moisture content but decreases with increase in moisture content above the normal. Torsional rigidity of jute is also affected at high moisture content. Toughness of jute is low on account of its low extensibility. Jute is highly hygroscopic and can absorb water up to about 5 times its own dry weight. This property introduces in jute an element of variance in weight under different relative humidity conditions.

Some salient physical properties of jute are given below:

- Density – 1.47gm/cc
- Average Fineness – 20 denier, i.e. weight in gm. of 900 metres of filament
- Tenacity – 4.2 gm/denier
- Average Extension at break – 1.2%
- Average Stiffness – 330 gm/denier
- Average Toughness Index – 0.02
- Hygroscopicity (average regain at 65% relative humidity) – 13%

2.2. Jute Geotextiles

Jute fibres is mechanically spun into yarns and woven into permeable and drapable fabrics (woven fabric) shown in **Fig. 1**.

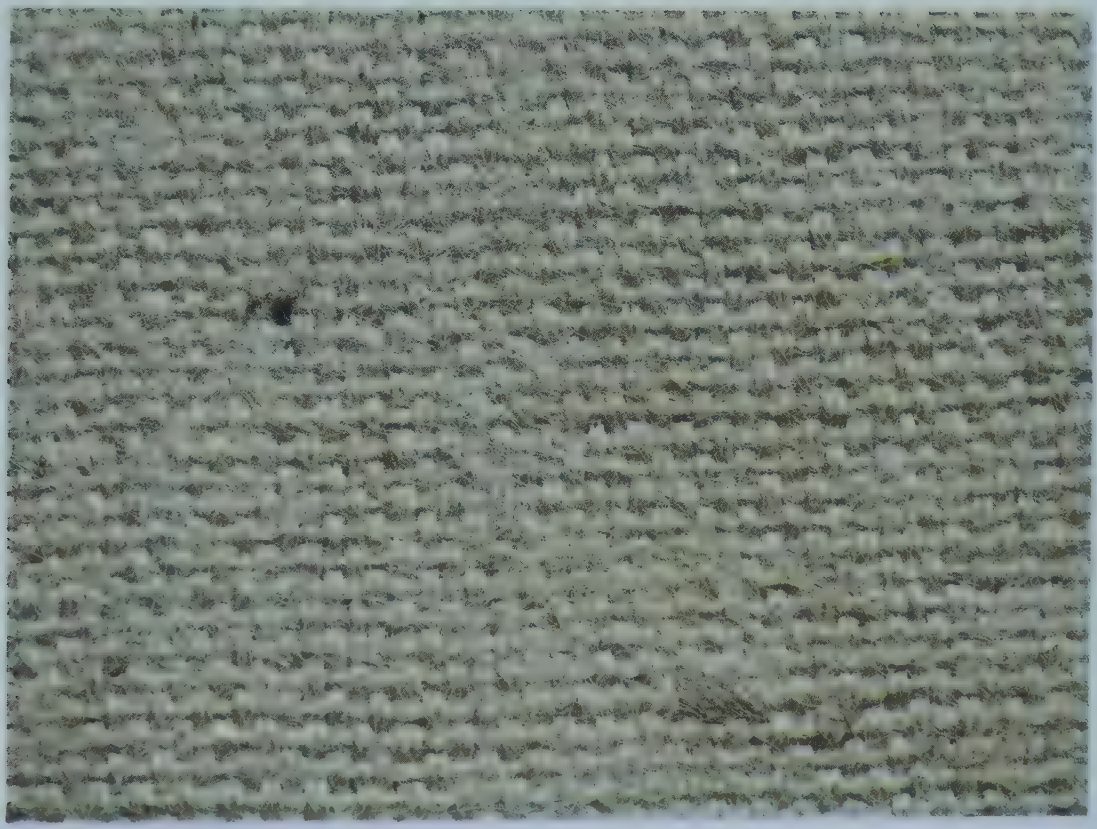


Fig. 1 Woven Jute Geotextile

JGT, being permeable, allows the water retained within soil to permeate across its plane and also to disperse along its plane. The extent of cross-permeability (termed "permittivity") and in-plane permeability (termed "transmissivity") depends on several factors, especially pore size of JGT (termed "porometry"). The porometry of JGT is also the determinant in retention of soil-particles on which it is laid. A properly designed JGT (in most cases, in relation to the mean diameter of the soil-grains i.e., d_{50}) arrests migration of the major portion of soil-particles and imparts strength to the soil-body by ensuring their retention within it.

2.3 Functions of JGT

A properly designed JGT is supposed to perform the following functions, usually simultaneously, in different application areas related to civil engineering:

- Separation
- Filtration
- Drainage
- Initial reinforcement

2.3.1 *Separation*

In road-construction, JGT is needed to separate the sub-base from the sub-grade to prevent the yield of the pavement under moving axle loads. Intermixing of two layers causes reduction in the effective thickness of pavement, thereby reducing the load carrying capacity and pavement life. Separation of two layers for at least one season-cycle helps in natural consolidation of the base-soil. Experiments have proved that once consolidation takes place, chances of subsidence of a part of any road or structure due to intermixing become substantially less. Biodegradability of JGT therefore does not normally pose any technical impairment after a season-cycle of its application.

2.3.2 *Filtration*

JGT, as filter is supposed to perform two contrasting functions – soil-retention on one hand and ensuring permeability of water through and along it on the other. JGT provides a technically superior solution to conventional granular graded filters used for control of erosion of high road embankments. JGT can be manufactured with pore-sizes commensurate with the median grain size of the base-soil to ensure their retention. At the same time, water is allowed to pass across and along JGT in the required measure without causing development of any differential overpressure. The functions of permittivity and transmissivity are therefore important. With a tailor-made JGT, differential water over-pressures across it can be effectively dissipated, while at the same time preventing migration of soil-particles.

JGT first retains the coarser particles of the soil. These coarse particles block smaller ones in the soil which in turn prevents migration of even smaller grains. This phenomenon which is known as ‘filter cake formation’ (**Fig. 2**) is in fact an indication of formation of a natural filter within the soil and its optimum consolidation. Soil properly overlain by JGT is seen to develop ‘filter cake’ usually within a period of 3 to 4 months from the date of application according to laboratory tests carried out in Research Institutes. Development of ‘filter cake’ is a sure indication of the base-soil having attained natural stability. Once the soil attains natural stability, function of any separating fabric – be it man-made or natural, becomes redundant. Biodegradation of a JGT therefore does not normally pose any deficiency in its expected performance as such.

Though formation of ‘filter cake’ happens within about 3 to 4 months from the date of application of JGT, it is advisable to ensure durability of JGT for at least one season-cycle.

2.3.3 *Drainage*

JGT performs drainage function within its own thickness. Proper drainage of soil accelerates its consolidation. Cohesion of the soil, as a result, is increased which in turn, accentuates the separation effect of the JGT.

JGT possesses a high degree of transmissivity, i.e., can drain water effectively along its plane. JGT is also capable of holding water to about 5 times of its own weight. In roads, lateral drainage of water from sub-base and sub-grade is critical. JGT used as a separator may facilitate the lateral evacuation of water from the road-structure and prevent water-accumulation at the sub-grade level.

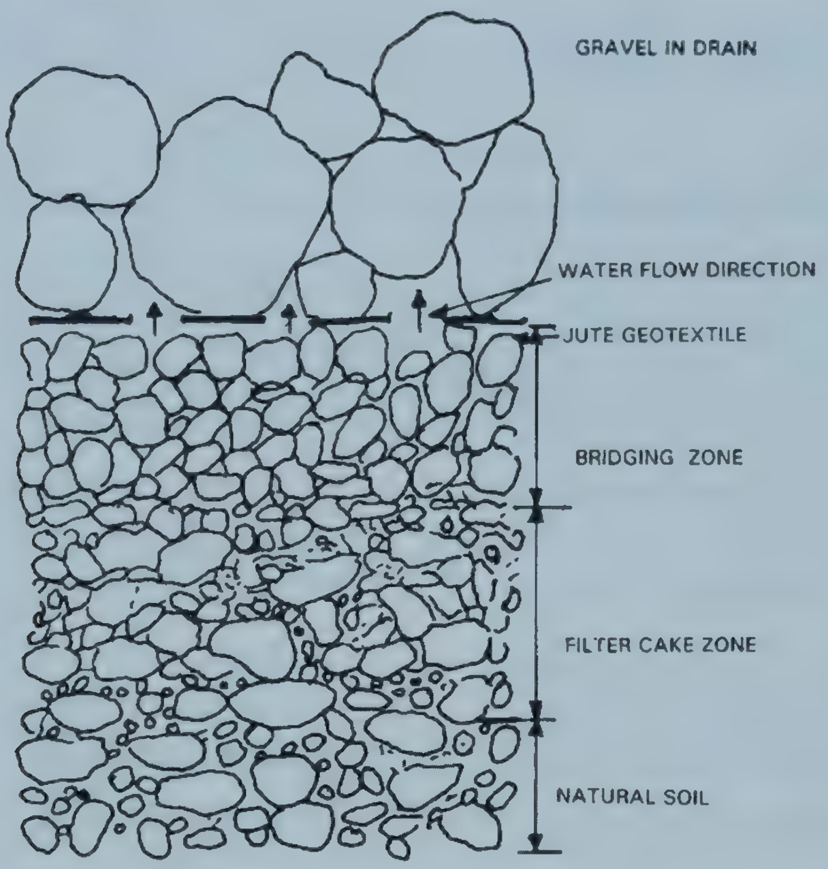


Fig. 2 Filter Cake Formation

2.3.4 *Initial Reinforcement*

JGT can reinforce soils which are usually weak in tension at the initial stages. Any large soil body e.g., an embankment, undergoes failure by vertical subsidence, lateral dispersion and rotational slides. When used in appropriate layers, especially across vulnerable planes of failure and distress, JGT can effectively control such failures. Soil-movement is curbed by its confining action. JGT also absorbs a part of the stress that could cause a shear-failure. Stability of such soil-structures is thus substantially enhanced enabling faster construction without removal of weak soil layers.

As has already been pointed out, any soil-mass tends to stabilize naturally if proper separation, filtration and drainage can be ensured. JGT can be manufactured with up to 40 kN/m tensile strength in both warp and weft directions and can impart sufficient strength to soil body in its initial performing phase. Once natural stability is achieved, it has been established that the technical function of a geotextile – natural or synthetic, becomes redundant.

2.4 Bio-degradability of JGT

Concurrent functioning of separation, filtration and drainage by the fabric ensures maximization of soil consolidation within two season cycles. Longer life of geotextiles beyond this period is thus not a technical necessity.

Jute fibres/yarns usually degrade after one year or so when in contact with soil as a result of microbial attack. Interestingly, laboratory studies and field applications have confirmed that the rate of loss in strength of JGT is compensated by the corresponding gain in strength of soil. The soil ultimately becomes intrinsically self-reliant needing no extraneous support.

Biodegradation of JGT is thus not a technical disadvantage as is usually thought of. JGT can be made to last for more than 2 years and even more by treating it with suitable eco-friendly additives. Research is on to develop suitable eco-friendly natural additives like tenin, bitumen, Phenol etc. that can impart a longer life to JGT (up to about 4 to 5 years) without affecting its mechanical properties.

2.5 Improvement in Pavement Performance by Application of JGT

Poor sub-grade often causes pavement-failures when strains accumulated under repeated dynamic loads of traffic exceed the permissible value. It often happens that the materials in the base course of the pavement puncture into the sub grade, reducing the required depth of the pavement decided on the basis of class of loading, rut depth and sub-grade strength. A poor sub-grade may also cause its lateral displacement along with the base-materials. Insufficient drainage of the surface water and also the entrapped moisture/water within the subsurface layers along with the seepage of water from the sides, often lead to road-failures.

Highly compressive soils like black cotton soil, saturated cohesive soils like clay with moisture content above the prescribed Plastic Limit pose problems in the shape of settlement and displacement. In case of saturated cohesive soils, vehicle loads may cause high pore water pressure to develop locally, which may “liquefy” the sub-grade soil.

JGT can help tackle all these problems effectively by segregating different layers of a road pavement, preventing movement of the sub-grade soil (sand-tightness) and facilitating penetration of water through its pores and dispersion of water along its plane. Load bearing capacity of the sub-grade gets enhanced due to concurrent function of separation, filtration and drainage by JGT. Treated woven JGT when laid on sub-grade enhances its CBR value (i.e., the undrained shear strength of the soil) due to separation and filtration functions of the fabric combined with the membrane effect.

JGT when placed over the sub-grade helps stabilize it in a number of ways. Besides preventing intermixing of the sub-grade and the sub-base, JGT also checks the upward movement of the fine particles in the sub-grade, provides frictional resistance against lateral dispersion and acts as a support membrane. The membrane effect leads to development of an upward reaction that partially relieves the downward imposed load. This is the reason why thickness of pavement required, works out to be lower than in case of conventional design.

3. PROPERTIES AND SELECTION OF JUTE GEOTEXTILE (JGT)

3.1 Properties of JGT

Choice of JGT is essentially an empirical exercise supported by practical experience. Retention criterion being the governing function of any geotextile, including JGT in case of road construction along-with tensile strength of JGT, finalization of the porometric features of JGT in relation to the grain size distribution of sub-grade soil is a must and most essential. It has also been observed in field applications that fulfillment of retention criterion of JGT also concurrently achieves the desired value of permittivity in relation to the practical drainage interaction of soil-subgrade and JGT.

Requirements of Tensile Strength of JGT: Tensile Strength of woven JGT shall be equal or higher than 25 kN/m in both directions (machine-direction and cross-direction). The tensile strength of fabric has been kept at 25 kN/m as higher tensile strength is usually not required for low volume roads.

Requirements of Porometry of JGT: The design of JGT involves deciding on the pore-size of JGT based on functional parameters which are indicated below.

(i) Requirements of Puncture and Bursting Strength: Puncture Strength of JGT shall be equal or higher than 0.5 kN whereas bursting strength shall be equal or higher than 3500 kPa. Further, JGT shall be sandwiched between 50 mm of sand-pad and placed over sub-grade which not only reduces any chance of puncture or bursting failure but also reduce the chances to develop any microbial activity in the JGT with possible soil-microbes. This will ensure a minimum life of one season to JGT to perform the function of initial reinforcement.

(ii) Requirements of Drainage: Fabric permeability (or permittivity) vis-à-vis soil permeability can be determined considering the following relationship:

If $d_{85} \leq 75\mu$ then $\psi_{JGT} \geq 10\ k_{soil}$

If $d_{85} \geq 75\mu$ then $\psi_{JGT} \geq k_{soil}$

To achieve maximum retention of top soil particles, the following relationship may be used:

If $d_{85} \leq 75\mu$ then $O_{95} \leq 2\text{-}2.5\ d_{85}$

If $d_{85} \geq 75\mu$ then $O_{95} \geq d_{85}$

Where, ψ_{JGT} is permittivity of fabric, d_{85} is the dia, 85% of soil particles are finer than that size, O_{95} denotes fabric aperture (Apparent Opening Size (AOS)) in JGT, 95% of pores are less than that size and k_{soil} is hydraulic conductivity of soil.

3.2 Selection and Technical Specifications of Jute Geotextiles for Roads

The overall requirements of woven Jute geo-textiles to be used in construction of low volume rural roads; should satisfy the specifications as given in Clause No. 4 (Table 1) of IS:14715 (Part I): 2016 as given below. Further, The overall requirements of woven, treated Jute geo-textiles to be used in construction of low volume rural roads; should satisfy the specifications as given in Clause No. 4 (Table 1) of IS:14715 (Part II): 2016 as given below.

Table 1 Requirements for Woven Jute Geotextiles of IS:14715 (Part I):2016 *(Clause 4)*

S. No. (1)	Characteristic (2)	Requirement (3)	Tolerance Percent (4)	Method of Test, Ref to (5)
i)	Construction	1/1 DW plain weave	–	Visual
ii)	Weight at 20 percent moisture regain, g/m^2, Min	724	–	IS 14716
iii)	Width, cm1)	As agreed	±1	IS 1954
iv)	Ends x Picks/dm, Min	94 x 39	–	IS 1963
v)	Thickness at 2 kPa, mm	1.85	±10	IS 13162 (Part 3)
vi)	Tensile strength in MD x CD, kN/m, Min	25 x 25	–	IS 13162 (Part 5)
vii)	Elongation at break in MD x CD, percent	10 x 10	±10	IS 13162 (Part 5)
viii)	Puncture resistance, kN, Min	0.500	–	IS 13162 (Part 4)

S. No. (1)	Characteristic (2)	Requirement (3)	Tolerance Percent (4)	Method of Test, Ref to (5)
ix)	Burst strength, kPa, Min	3500	–	IS 1966 (Part 1) or IS 1966 (Part 2)
x)	Permittivity at 50 mm constant head, sec^{-1}, Min	350×10^{-3}	–	IS 14324
xi)	Apparent opening size (A.O.S.), O_{95}, Micron	150-400	–	IS 14294

[1]Width of the fabric shall not be less than 100 cm

Table 1 Requirements for Treated Woven Jute Geotextiles of IS:14715 (Part II):2016 *(Clause 4)*

S. No. (1)	Characteristic (2)	Requirement (3)	Tolerance Percent (4)	Method of Test, Ref to (5)
i)	Construction	1/1 DW plain weave	–	Visual
ii)	Weight at 20 percent moisture regain, g/m^2, Min[1]	627	–	IS 14716
iii)	Width, cm[2]	As agreed	±1	IS 1954
iv)	Ends x Picks/dm, Min	85 x 32	–	IS 1963
v)	Thickness at 2 kPa, mm	1.70	±10	IS 13162 (Part 3)
vi)	Tensile strength in MD x CD, kN/m, Min	20 x 20	–	IS 13162 (Part 5)
vii)	Elongation at break in MD x CD, percent	8 x 8	±10	IS 13162 (Part 5)
viii)	Puncture resistance, kN, Min	0.400	–	IS 13162 (Part 4)
ix)	Burst strength, kPa, Min	3100	–	IS 1966 (Part 1) or IS 1966 (Part 2)
x)	Permittivity at 50 mm constant head, sec^{-1}, Min	350×10^{-3}	–	IS 14324
xi)	Apparent opening size (A.O.S.), O_{95}, Micron[3]	150-400	–	IS 14294

[1]For river bank protection purpose, the 627 gsm fabric to be treated with suitable additives.

[2]Width of the fabric shall not be less than 100 cm.

[3]A.O.S. (O_{95}) is decided on the basis of average particle size distribution of soil and its hydraulic conductivity.

4. PAVEMENT DESIGN WITH APPLICATION OF JGT

4.1 The Design Process

For working out, suitable and economical pavement designs using JGT for the low volume rural roads, emphasis should be given to the traffic estimation, subgrade strength evaluation, selection and properties of JGT and the design criteria followed. The use of JGT is usually recommended for low strength subgrades (i.e. CBR 2 to 6%)

Estimation of traffic: Where no road is existing at present, the estimation of traffic over the design life cannot be made directly on the basis of traffic counts. In such cases, it would be most expedient to carry out traffic counts on an existing road, preferably in the vicinity with similar conditions. Based on such traffic counts on an existing road catering to a known population and known amount of agricultural/industrial produce, the amount of traffic expected to ply on the proposed road can be suitably worked out.

Assessment of subgrade strength: It is necessary to scientifically carry out a soil survey and test the representative samples for standard IS classification tests, compaction tests and CBR. The depth of Ground Water Table (GWT) and its fluctuations, annual rainfall, and other environmental conditions that influence the subgrade strength must be investigated.

Determination of pavement thickness and composition: It is necessary to carry out a comprehensive field materials survey and the needed laboratory tests on representative samples to maximize the use of locally available materials for use in sub-base, base and surface courses as such or after suitable blending. Using the design traffic parameter and the subgrade strength parameter, the pavement thickness and composition can be determined.

4.2 Traffic Parameters

The design traffic is considered in terms of cumulative number of Standard Axle to be carried during the design life of a rural road and the procedures as given in para 2.1.1 in IRC:SP:72 are to be followed.

Assuming a uniform traffic growth rate 'r' of 6% over design life (n) of 10 years, the cumulative ESAL applications (N) over design life can be computed using following formula:

$$N = T_0 \times 365 \times [((1+0.01\ r)^n - 1) / (0.01\ r)] \times L$$

Where, r = Traffic Growth Rate = 6%, for rural roads

T_0 = ESAL per day = Number of commercial vehicles per day x Vehicle Damage Factor

L = Lane Distribution Factor = 1 for single lane

n = Design life = 10 years, for rural roads.

Traffic Categories: For pavement design, traffic has been classified into nine categories as given in IRC:SP:72-2015.

Traffic Category	Cumulative ESAL Applications
T_1	10,000-30,000
T_2	30,000-60,000
T_3	60,000-100,000
T_4	100,000-200,000
T_5	200,000-300,000
T_6	300,000-600,000
T_7	600,000-1,000,000
T_8	1,000,000-1,500,000
T_9	1,500,000-2,000,000

4.3 Subgrade Strength Evaluation

As per MORD Specifications for Rural Roads, subgrade can be defined as a compacted layer, generally of naturally occurring local soil, assumed to be 300 mm in thickness (for low volume roads) just beneath the pavement crust, and is made up of in-situ material, select soil or stabilized soil, that forms the foundation of the pavement. The subgrade in embankment is compacted in two layers, usually to a higher standard than the lower part of the embankment. It should be well compacted to limit the scope of rutting in pavement due to further compaction/consolidation during the service life of pavement. In cuttings, the cut formation, which serves as the subgrade, is treated similarly to provide a suitable foundation for the pavement.

The subgrade, whether in cutting or in embankment, should be well compacted to utilize its full strength and to economize on the overall pavement thickness. The current MORD Specifications for Rural Roads require that the subgrade should be compacted to 100% Maximum Dry Density achieved by the Standard Proctor Test (IS 2720-Part 7). The material used for subgrade construction should have a dry unit weight of not less than 16.5 kN/m^3.

Soil surveys: It is necessary that a soil survey along and across the road alignment is carried out following the laid down-procedures and that the results of all field and laboratory investigations are made available to the designer. During the soil surveys, the depth and fluctuations of GWT must also be recorded. All the representative samples of subgrade soils must be subjected to the simple classification tests (wet sieve analysis, liquid and plastic limits) and the soil group shown against each representative sample, ensuring that at least 3 samples are taken per kilometre length, even if the same soil type continues.

For each of the soil groups thus identified, at least one CBR test should be conducted with the soil compacted to the Standard Proctor density and at a moisture content corresponding to the wettest state, according to the expected site conditions.

Subgrade Strength: As applicable in the conventional roads for the pavement subgrade design of the new roads, the subgrade strength may be evaluated in terms of CBR value.

- The CBR of the subgrade can be estimated by conducting actual CBR tests in the laboratory, as per the standard test procedure laid down in IS 2720 (Part 16).
- Minimum 3 tests per km are required to reach the design CBR.
- 4-day soaked CBR tests are required to be conducted in areas having rainfall intensity greater than 1000 mm per year.
- Cl. No. 4.2.1.1 of IRC:SP:72-2015 may be followed in addition to the above.

4.4 Pavement Composition

Fig. 3 presents a typical cross section of a rural road with application JGT.

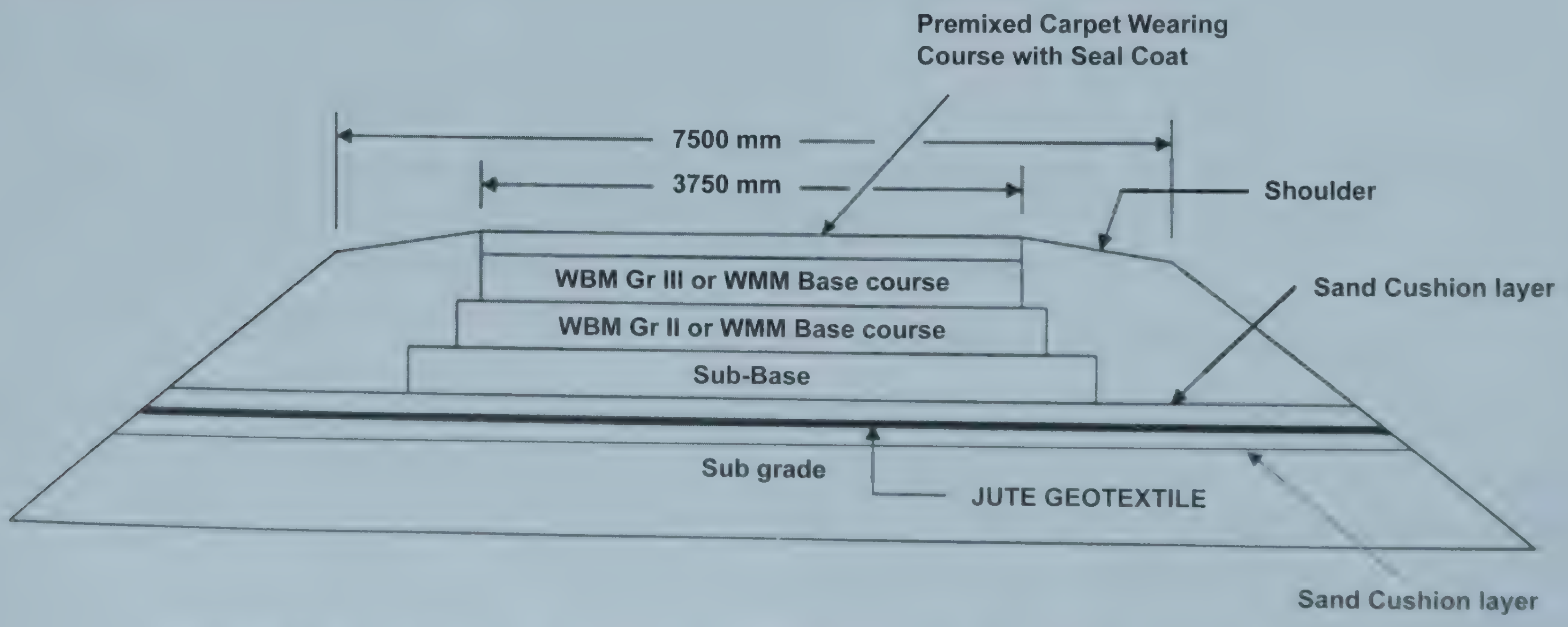

Premixed Carpet Wearing Course with Seal Coat
7500 mm
3750 mm
Shoulder
WBM Gr III or WMM Base course
WBM Gr II or WMM Base course
Sub-Base
Sand Cushion layer
Sub grade
JUTE GEOTEXTILE
Sand Cushion layer

Fig. 3 Typical Cross Section of a Rural Road with Application of JGT

Sub-base course: For granular sub-base, the materials generally used are natural sand, moorum, gravel, crushed stone, crushed slag, brick metal, kankar or combination thereof depending upon the grading required as per Clause 401 of the MORD Specifications for Rural Roads.

Base course: For rural roads designed for cumulative ESAL repetitions more than 1,00,000, unbound granular bases which comprise conventional Water Bound Macadam (WBM), Wet Mix Macadam (WMM) or Crusher Run Macadam Base (CRMB) are adopted as per Clauses 405, 406 and 411 of the MORD Specifications for Rural Roads. Where hard stone metal is not available within economical leads, a cement stabilized base/sub base can be provided as per Clause 404 of the MORD Specifications for Rural Roads.

Surfacing: For rural roads designed for cumulative ESAL repetitions, over 100,000, a bituminous surface treatment of 2-coat surface dressing or 20 mm premix carpet is recommended, as per MORD Specifications for Rural Roads.

Jute Geotextile: Selected JGT shall be placed at the interface of Sub-grade and Sub-base/ Base course, sandwiched between 50 mm thick sand-pad. The JGT shall be laid to full roadway-width in case of new construction. In existing pavement if widening is undertaken; the JGT shall be laid to full width of the widened roadway.

4.5 Estimation of Pavement Thickness

The methodology developed for use of JGT in low volume rural roads follows a mechanical approach. The thickness of pavement for low volume roads is estimated considering elastic moduli of pavement component materials, traffic volume, wheel load, and the tyre pressure, using a finite element method based programme. The geotextile reduces the initial vertical strain over subgrade and by the time it degrades after one or two seasons, the subgrades gets consolidated and its strength is increased. The design is based on permissible initial vertical compressive strain over subgrade to address the rutting failure.

The design has been done for the following conditions:

1) Cumulative Traffic: $30000 \leq ESAL \leq 2000000$
2) Subgrade strength: $2 \leq CBR \leq 6$
3) Bio-degradability of JGT with respect of time do not cause any hindrance.

Pavement Analysis

The analysis has been carried out considering the pavement to be a three layer system as shown in **Fig. 4**.

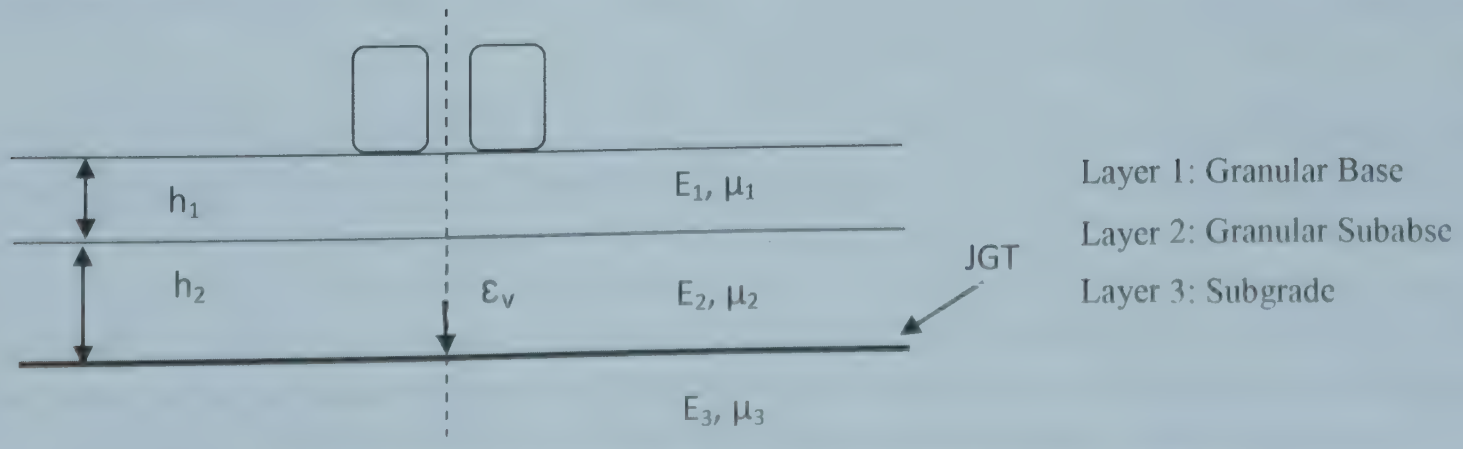


Fig. 4 Three Layer System for Pavement Analysis

Finite Element Method (FEM) has been employed to carry out the linear elastic analysis. The FEM model used is shown in **Fig. 5**.

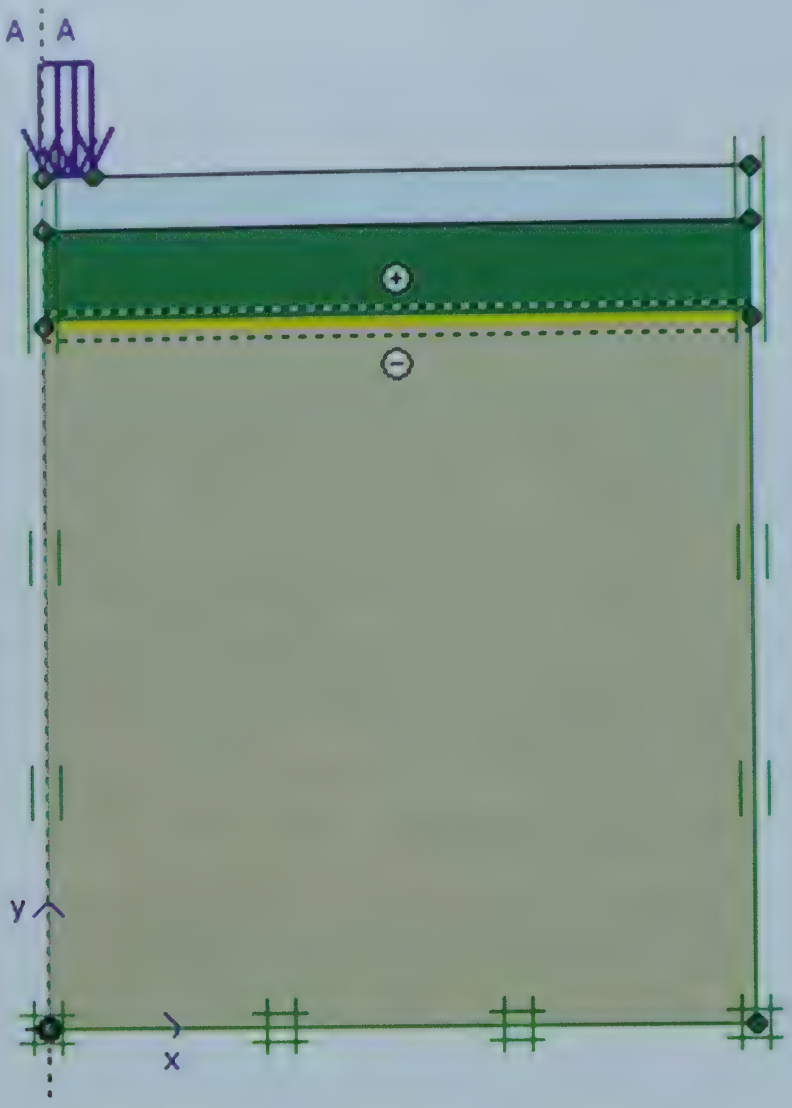


Fig. 5 FEM Model for Pavement Analysis

The following input have been adopted for analysis:

$E_{subgrade}$ = 10 * CBR
$E_{sub-base}$ = 200 MPa
E_{base} = 450 MPa
$E_{geotextile}$ = 80 kN/m (at 2% strain)
Poisson's ratio = 0.35 for all layers
Axle Load = 80 kN
Tyre Pressure = 0.56 MPa

From the analysis, it was observed that there is a reduction of 8 to 16% in the vertical compressive strain over subgrade for a subgrade strength of 2 to 6%.

Proposed design thicknesses are provided in the **Table 2** for a sub-grade CBR range of 2% to 6%, for which Jute geotextile may be used. It is observed from **Table 2** that the reduction in thickness is of the order of 25 to 50 mm, compared to the design charts provided in IRC:SP:72 for conventional design of pavement without Jute geotextile. Therefore same layer thicknesses may also be adopted with application of JGT for these low strength subgrades (2%-6%). Use of JGT will improve the durability and performance of the pavement. However, a decision regarding use of JGT should be based on the basis of its availability, material cost, transportation cost and overall economy in construction.

Table 2 Design Pavement Thickness (mm) for Low Volume Roads using JGT for a Range of Sub-grade CBR (2% to 6%)

Subgrade Strength	Traffic Category																	
CBR (%)	T1		T2		T3		T4		T5		T6		T7		T8		T9	
	Base	Sub-base	Base	Sub-base	Base	Sub-base	Base	Sub-base	Base	Sub-base	Base	Sub-base	Base	Sub-base	Base	Sub-base	Base	Sub-base	Bituminous Layer (BM)
Very Poor CBR = 2	100	150	100	200	150	175	150	225	150	250	150	300	150	350	225	300	225	300	50
Poor CBR = 3 to 4	100	150	100	175	150	150	150	200	150	225	150	250	150	300	225	250	225	250	50
Fair CBR = 5 to 6	100	100	100	150	100	150	150	175	150	200	150	200	150	250	225	200	225	200	50

Note: For all the traffic categories beyond T2 (except for CBR 2%), a thin bituminous surfacing (premixed carpet or two coat surface dressing) should be provided.

5. CONSTRUCTION ASPECTS

5.1 Installation of JGT in Road Construction

The following sequence should be followed for installation of JGT:

1. Sub-grade is to be excavated to the required level, cleared of all foreign materials and compacted to the OMC. Sub-grade should be done up to the specified profile. Vegetation, if any, should be uprooted and the area leveled with earth and rolled.
2. A thin cushion of local sand of about 25 mm thick to be spread over the prepared sub-grade to facilitate better drainage and reduce chances of microbial attack.
3. Selected JGT should be laid by unrolling, ensuring proper drapability so that the fabric touches the sand layer at all points and stapled at an interval of about 750 mm with longitudinal overlaps of 100 mm and lateral overlap of 300 mm. Staples should be preferably U-shaped nails (11 gauge).
4. A thin cushion of local sand of about 25 mm thick to be spread over the JGT to prevent puncture/damage due to rolling of the overlying sub-base/base-layer.
5. The first layer of aggregates in the sub base-layer should be spread with grading as recommended. No traffic should be allowed on an un-compacted sub base with less than 200 mm (300 mm for CBR greater than or equal to 3) thickness laid over JGT.
6. Any rut that may develop during construction should be filled in.
7. Parallel rolls of JGT should be overlapped by 100 mm (**Fig. 6**) and stapled (**Fig. 8**).
8. For application along curves, JGT should be folded or cut and overlapped in the direction of the turn. Folds in JGT should be stapled at an interval of 300 mm in curves (**Fig. 7**).

9. Before covering up the JGT, its condition should be assessed for any damage during construction/installation. Torn/damaged portions may be covered by pieces of JGT and duly stapled on all sides preferably at an interval of 300 mm. The extent of overlap should be such as to fully cover the damage/torn portion plus at least 75 mm beyond on all sides.

10. Often the sub-surface water is drained through the JGT and sand medium to the shoulders of a carriage way. In such cases, shoulder drains are required to be constructed either beneath the edge of the shoulder or immediately adjacent to its edge. In the event of existence of black cotton soil or expansive clay, porous drain pipes may also be inserted within the shoulder drain to augment drainage-efficiency.

11. Installation procedure is similar to what has been mentioned for open JGT-Encapsulated trench drains under the section.

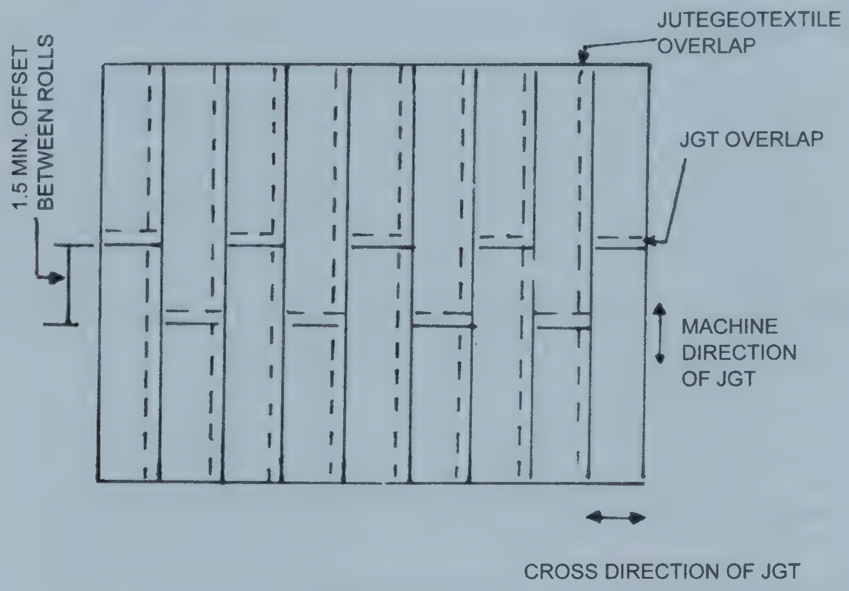


Fig. 6 Direction of Covering and Overlap

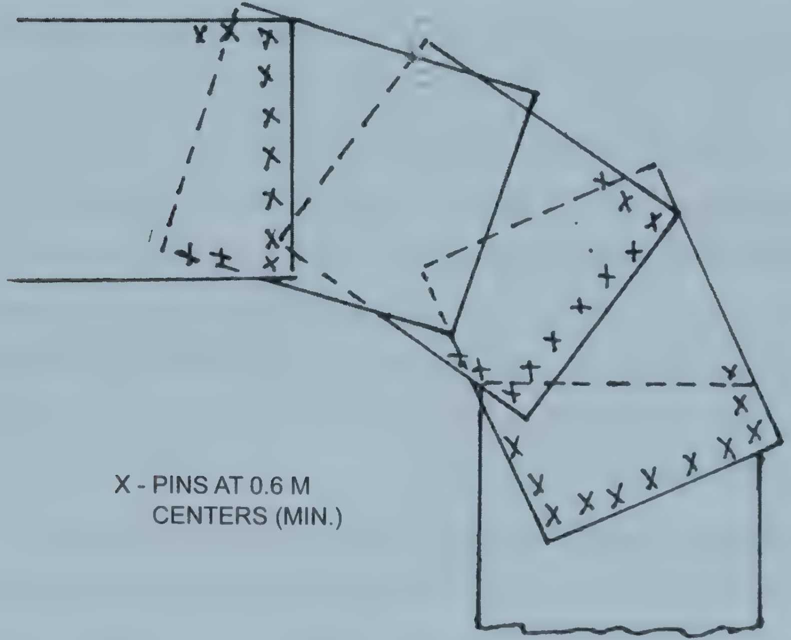


Fig. 7 Placement of JGT in Straight Alignment and Curves

12. Performance of the pavement with JGT should be monitored closely, especially with regard to development of pot holes, subsidence, road side drainage, dispersion of sub-grade etc.. Frequency and extent of surface treatment and also re-sectioning needed are also to be noted. Special attention is necessary during and after the rains. Pot holes should be immediately restored. Surface drainage over the pavement should not be hindered due to malfunctioning of road side and shoulder drains.

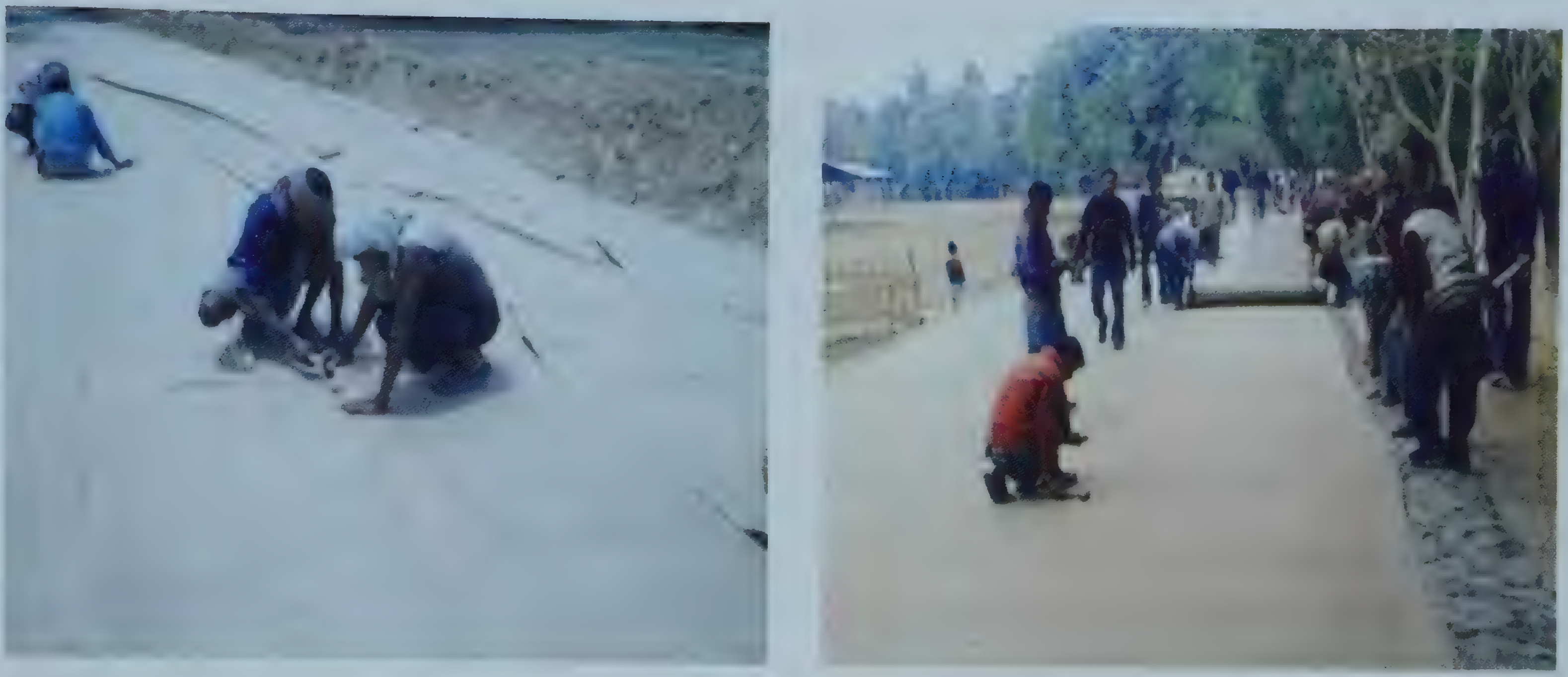


Fig. 8 Installation of JGT in the Field

Reinforcement Jointing: Required overlapping length must be detailed in the drawing by the designer. An overlap of 300 mm or as indicated by Engineer shall be provided between the adjacent rolls and the overlap should have sufficient anchorage length so that overlaps are strong enough to carry design loads.

End Anchorages: The roll should be unwound a small amount by pushing the roll in the direction of the reinforcement run. The base end of the reinforcement now exposed should be secured by weighting or pinning it to the formation. When the roll is completely unwound, the free end of the reinforcement should be hand tightened and secured by weighting or pinning.

5.2 Transportation, Storage and Handling of JGT

5.2.1 *Transportation*

JGT in the form of roll or bale can be easily handled and transported. Jute yarns are inherently robust, but care is to be taken to keep them free from moisture (being hygroscopic) and fire. It can be shipped either as a bulk or a break-bulk cargo. A bale weighs around 340 kg. (680 m^2) and may consist of a number of lengths (8 to 10) depending on the required individual roll length.

5.2.2 *Site unloading*

A fork lift or front-end loader fitted with a long tapered pole (carpet pole/stinger) is recommended for unloading JGT rolls. The carpet pole is inserted into the core of a JGT roll which is then unloaded from the truck. Nylon straps/ropes/roll pullers may also be used. Not more than three JGT rolls should be lifted and unloaded at a time. Use of chains and cables for unloading purposes is discouraged. A tarpaulin, a sheet of plastic or the like should be placed on ground for initial storage of JGT.

5.2.3 *Storage*

Prolonged storage of JGT in warehouse is discouraged as JGT is susceptible to microbial action and loss of strength. JGT should be provided with a water-proof cover for protection against rains and moisture. After receiving JGT, it should be used as early as possible. But if needed, it can be stored for about 6 months at site in a warehouse, ensuring that the material is well protected and not in direct contact with soil, water and sunlight. Humidity, temperature variation, lack of air-circulation and abnormal moisture absorption affect the quality of JGT. Storage of JGT therefore calls for care. The main thrust should be on safe transportation and storage of JGT at site without damage and undue exposure of the material to adverse climatic conditions.

5.2.4 *Site Handling*

As already stated, JGT rolls should be provided with a protective wrapping. It should be kept above not over the ground and should be covered with tarpaulin or thick plastic sheet.

Exposure of JGT to moisture/water may pose handling problems. As JGT can absorb water up to 5 times of its own dry weight, handling wet JGT becomes more difficult than handling moisture-free JGT. The cores of JGT-rolls usually made of laminated paper are susceptible to damage on being exposed to moisture/water and should therefore be kept dry.

5.3 Durability of JGT

It has been established through laboratory tests on samples of JGT with varying linear density that its biodegradation depends on environmental factors. It has been observed that jute degrades faster in an acidic environment having pH value less than 5.2. The rate of degradation of JGT is generally fast in the initial stages, but slows down subsequently. On the other hand, when pH is in a higher range (above 7) i.e., in an alkaline environment, the laboratory tests conducted by IIT, Delhi have indicated that higher is the linear density of yarns in a JGT, quicker is its degradation, though more elaborate studies are needed to come to a definite conclusion. At present, it is recommended that the JGT should be used only when pH of the material in which it is proposed to be placed, is in the range 5 to 7 (neither acidic nor alkaline).

Bacteria and fungi are two main groups of micro-organisms responsible for the microbial decomposition of any natural Geotextile. Moisture plays a key role in this respect. It has been reported that the minimum moisture requirements for the growth of bacteria and fungi in JGT are 20% and 17% respectively. Jute attains the aforesaid moisture contents when the relative humidity in the atmosphere is 90% and 80% respectively.

Temperature is also instrumental for bacterial and fungal attacks on jute. A temperature of 37^0C is the most favourable temperature for bacterial growth and 30^0C for growth of fungi in JGT. Both sunlight and rain cause quick degradation of JGT. The organic content of soil accelerates the decay of jute fibre.

The degradation studies on jute so far conducted indicate that the mechanism of its biodegradation is complex, being dependent on interaction of a number of influencing factors. To prolong the durability of JGT, rot-resistant chemicals are presently used. The chemicals are essentially copper based compounds – usually Copper Naphthenate and Cuprammonium. The former is a non-leachable compound and costlier. The latter gets leached on continuous exposure to water. Bitumen (90/15 grade) is also in use currently use as a coating on JGT for the same purpose, in addition usually to its application in bank-protective works in rivers and waterways. As a result of the application of rot resistant chemicals/bitumen, the life of a JGT can be prolonged to about 4 to 5 years, subject to the specific subsoil ambience.

6. QUALITY CONTROL TESTS

Selection of the right type of JGT for a specific application is of vital importance. Considering the function of all geosynthetics to be similar, general quality control tests have been adopted here for JGT also. As the test standards of such Geotextiles are not uniform across all countries, references have been drawn from the American Standards (ASTM standards) for the sake of uniformity, where Indian Standards are not available. The properties of JGT have also been drawn from "Jute Geotextiles – a survey made by International Trade Centre, UNCTAD/GATT" where deemed applicable.

The section has been sub-divided into three categories:

- Physical Properties
- Mechanical Properties
- Hydraulic Properties

6.1 Physical Properties

Physical properties mentioned in this subsection refer to JGT, as presently manufactured. They are indicative only and not the critical design properties of the product.

6.1.1 *Mass per unit area*

This is an important property having a direct impact on the cost and mechanical properties. After 24 hours of conditioning at standard ambient conditions of temperature at 21^{0}C ± 2^{0}C and relative humidity at 65% ± 5%, the following nomenclatures for civil engineering applications may be adopted in case of untreated JGT in respect of mass per unit area.

6.1.2 *Thickness*

This is an important property in connection with transmissivity of JGT. It is measured between the upper and lower surfaces of the JGT at a specified pressure. ASTM D 5199/BIS-13162 part III stipulates that the accuracy should be at least 0.02 mm under a pressure of 2 kPa. Thickness of 724 gsm woven JGT, under a pressure of 2 kPa, will be 1.85 mm. Thickness of Open Weave JGT used for slope protection works ranges from 2 mm to 8 mm. Thickness of commonly used JGT ranges from 2 mm to 8 mm.

6.1.3 *Porometry*

This is a critical property for permittivity and soil retention. JGT can be manufactured with open weave like nets or as closely woven fabrics with a pore size of 100 micron or above. A finer pore-size of JGT treated with rot-resistant chemicals/bitumen reduces OAR (Open Area Ratio) reducing/permittivity of JGT and inducing clogging.

6.1.4 *Pore sizes can be measured by three different techniques-*

a. *By using a calibrated microscope:*

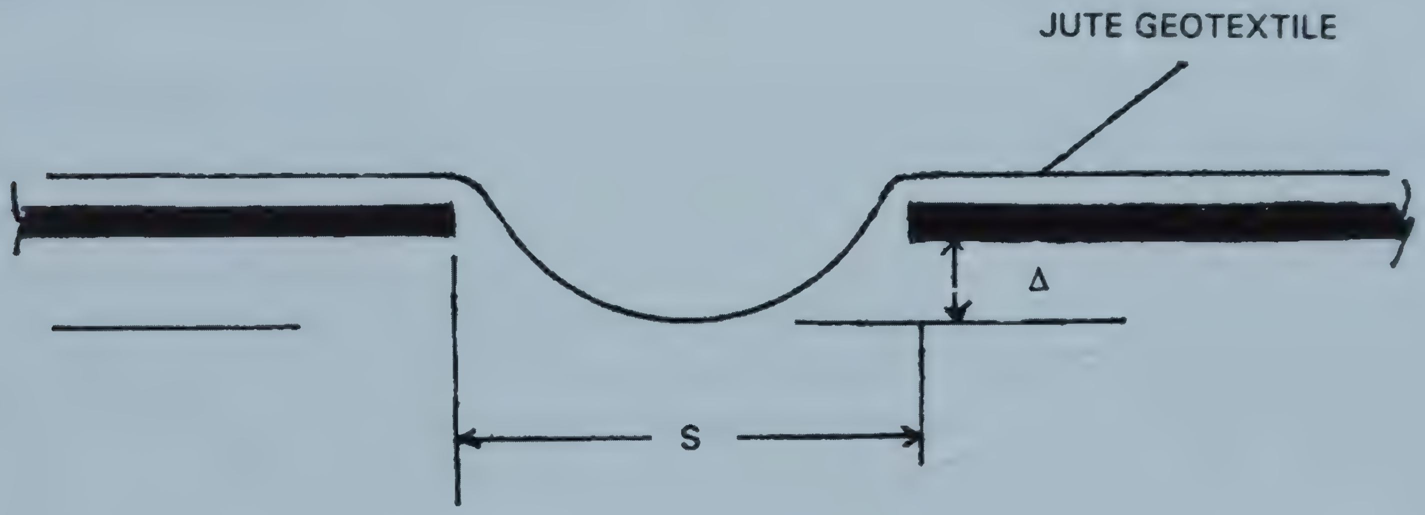
In the case of rectangular pores, the smaller dimension is taken as the pore size. A grading curve for the pore size distribution can then be represented on a semi-logarithmic graph which is similar to a particle size distribution graph for a soil.

b. *By reverse dry sieving technique:*

Special glass beads (ballotini) of known size are vibrated on the JGT-fabric having unconfirmed mesh-size or porometry. The percentage of the glass beads passing through it is recorded and the test is repeated for successive smaller grades of glass beads. The pore size grading curve may be drawn on the basis of the findings.

6.1.5 *Drapability*

JGT should have the ability to shape itself in keeping with the soil-surface-contours and to establish full contact with the surface. The extent of drapability is assessed by measuring the sag (Δ) in mm of the JGT in between two points (S) also in mm and graph may be drawn with the values so obtained. It is also a measure of JGT's "flex-stiffness" i.e., bending of JGT under its own weight between two points (vide test method in ASTM D 1388). Drapability of jute is more when it is wet.



WHERE S IS A VARYING OPEN SPAN (mm)
AND Δ IS SAG(mm) OF JGT

Fig. 9 Drapability Test for JGT

6.2 Mechanical Properties

Mechanical properties of JGT are basically indicative of the product's resistance to mechanical stresses developed as a result of application of loads and/or installation conditions. The tests that may be used for determining mechanical properties of JGT are tensile strength, puncture strength, burst strength and tear strength. Test for frictional resistance (soil-JGT friction) is also important.

6.2.1 *Tensile Strength*

The test for Tensile Strength is performed as per ASTM D4632 or the relevant Indian Standards. The JGT specimen is stretched through one end but gripping it at two ends till its failure. While extending the sample, both load and deformation are to be measured and noted. Other tensile test methods are Narrow Strip Test (ASTM D 751) and Wide Width test (ASTM D 4595/BIS – 13162 Part 5). A sample of 200 mm and 100 mm width respectively will serve the purpose for the aforesaid tests. Maximum tensile stress is often referred to as ultimate strength. Woven JGT (heavy type) can be manufactured to an ultimate strength of 40 kN/metre, in both directions, under normal manufacturing process.

6.2.2 *Puncture Strength*

A puncture rod is pushed through the JGT-sample clamped to an empty cylinder. Resistance to puncture is measured in N or kN. Woven JGT (heavy type) may be manufactured to possess a puncture strength of 500 N.

6.2.3 *Burst Strength*

The test is known as Mullen Burst Test and is described in BS 4768 and ASTM D 3786. The JGT is given a shape of a hemisphere by inflating it by a rubber membrane. The sample bursts when no further deformation is possible. This is an index test and is used primarily for quality control. The unit is kilo Pascal (kPa).

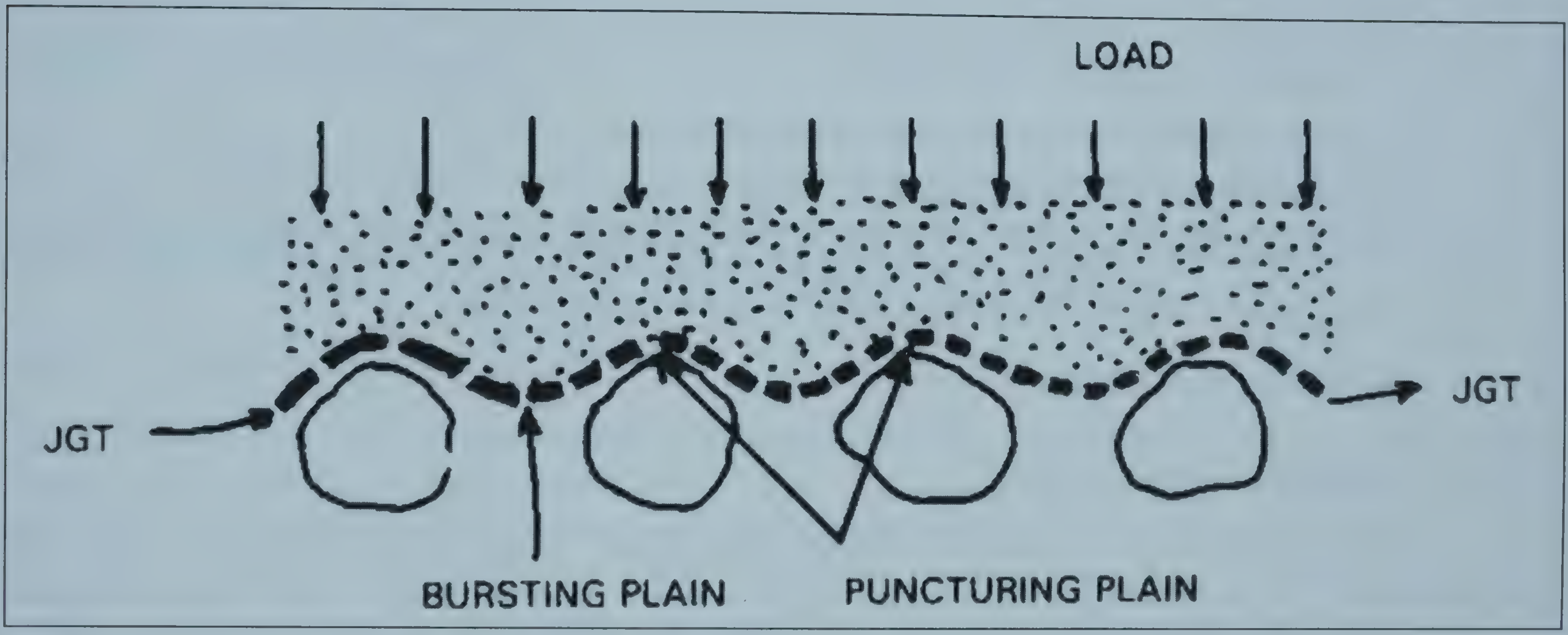


Fig. 10 Representation of Bursting Plain and Puncturing Plain

6.2.4 *Tear Strength*

JGT should be inserted into a tensile testing machine with an initial 150 mm cut (Trapezoidal Tearing Strength Test). The load stretches the fabric before it tears. The test is described in ASTM D 4533/BIS 14293. The unit is kilo Newton (kN).

6.2.5 *Frictional Resistance*

This property can be determined either by the direct Shear Test using a shear box or the Pull out Test. The sample is placed between two parts of a shear box with its lower half fixed. The upper half filled with soil is moved horizontally relative to the lower half at a constant rate of displacement. The maximum horizontal force required to move the top half is used to calculate frictional resistance by dividing it by the specimen area.

In the pull out test, the JGT sample sandwiched between two halves of the box fitted with the soil is pulled by the jaws at a constant rate of displacement. The pull-out force is a function of JGT-extensibility, length of embedment, redrawal stress etc.

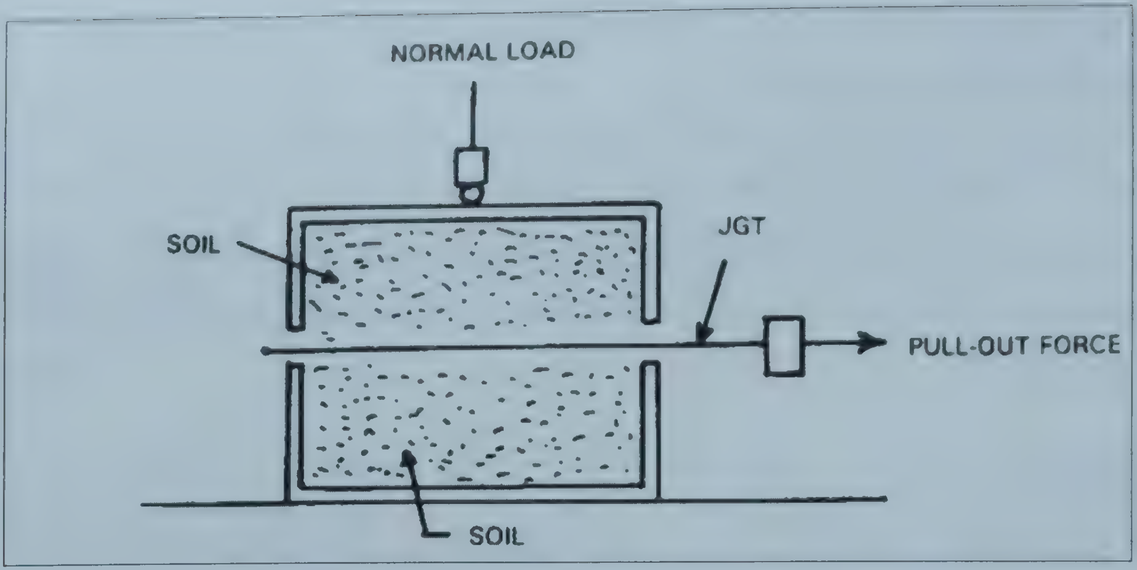


Fig. 11 Principles of Pull-Out Test

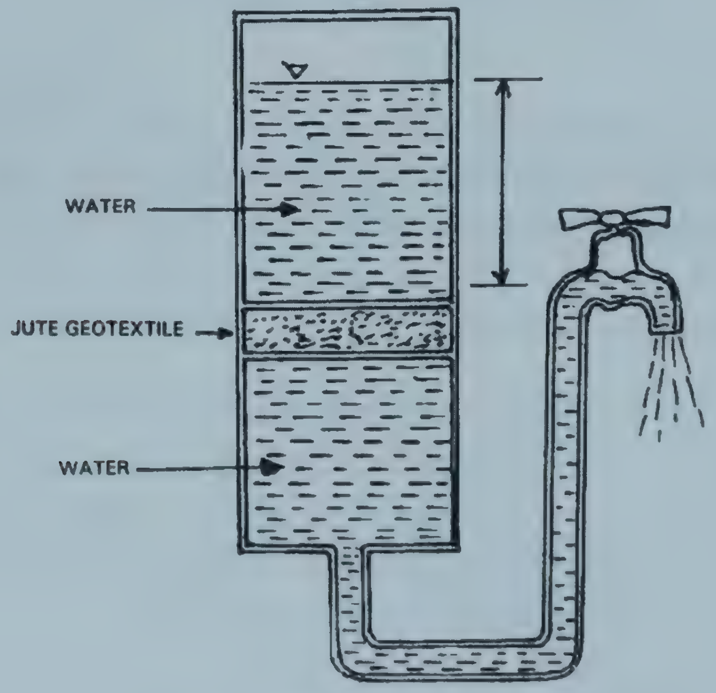
It may be noted that determination of values of different tests indicated above depends largely on the testing procedures like the method of gripping the sample, slippage of the sample, rate of deformation, sample-size etc. The stress-strain curve of JGT sample indicates the following:

- Maximum tensile stress (ultimate strength)
- Strain at failure (i.e., elongation at break)
- Modulus of deformation (i.e., the slope of the initial portion of the stress-strain curve)
- Toughness (usually the area under the stress-strain curve)

6.3 Hydraulic Properties

6.3.1 *Permittivity of JGT (Ψ)*

Permittivity is the measure of hydraulic conductivity of JGT across its plane in relation to the fabric thickness. If permittivity of JGT is known, the flow capacity of JGT can be assessed for any given hydraulic gradient and flow area. It is expressed in reciprocal of time (sec-1) and is derived from Darcy's Law.



JGT. - PERMITTIVITY TEST

Fig. 12 Hydraulic Permitting Test

$$q = k_g \times i_g \times A$$
$$= k_g \times \Delta_{hg} \times A / t_g$$

Where, k_g stands for coefficient of cross permeability of JGT (m/s),

i_g is hydraulic gradient (Δ_{hg} / t_g) (dimensionless)

Δ_{hg} = head loss across JGT (m) or in appropriate linear unit

A = JGT cross-section (m^2)

t_g = thickness of JGT (m) or same unit as of Δ_{hg}

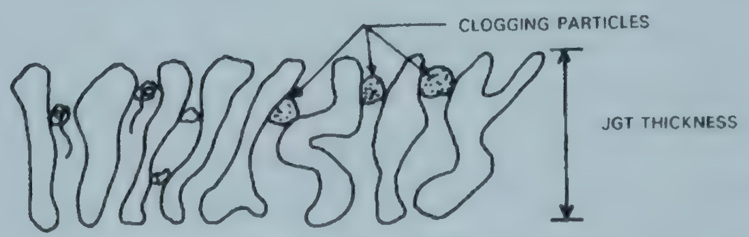
The ratio k_g / t_g is termed as the permittivity of JGT (Ψ) and is therefore equal to $q / \Delta_{hg} \times A$.

6.3.2 *Transmissivity of JGT*

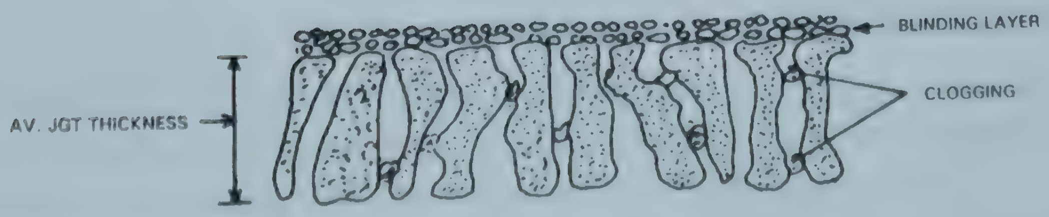
Transmissivity is the property of JGT to transmit flow along its plane and is a function of its thickness and structure. In this case, the cross-sectional area of flow 'A' would be equivalent to $t_g \times w$, where t_g is the thickness and w is the width of JGT transmitting in-plane flow. Rate of discharge, Q would equal $t_g \times w \times k_p \times i$, where k_p is the co-efficient of normal permeability and i the hydraulic gradient. The product $t_g \times k_p$ is called hydraulic transmissivity (θ), where Q is equal to $\theta \times w \times i$. It is thus evident that transmissivity is directly proportional to the hydraulic gradient. It is pertinent to note that in certain types of non-woven JGT, high normal stress reduces transmissivity drastically. With given values of hydraulic gradient and normal stress level, transmissivity can be calculated by dividing the flow rate ($m^3/s/m$) by the hydraulic gradient.

6.3.3 *Clogging Potential of JGT*

There are two test methods available to evaluate clogging potential of JGT – Gradient Ratio test and Hydraulic Conductivity Ratio (HCR) test. The first method does not simulate the field conditions in respect of compaction and confinement which the latter does. ASTM D 5567 describes methods for the HCR test. ASTM D 5101 mentions about the Gradient Ratio method in which water is allowed to flow downwards through a vertical column of the soil placed over the JGT sample. Hydraulic gradient is measured at two locations above the JGT. If the ratio of the flow exceeds a prescribed limit, it indicates the vulnerability of the JGT to clogging.



TYPICAL CLOGGING IN JGT



BLINDING AND CLOGGING IN JGT

Fig. 13 Clogging and Blinding in JGT

The intention/objective of either of these two methods is to ensure a long term flow-compatibility between soil and JGT. Clogging-proneness of a JGT is low when the flow rate decreases with time and then attains a stable value over a time. Clogging-potential is high when the flow rate continues to decrease with time and does not stabilize. Piping-failure is indicated when the flow rate goes on increasing with time.

7. OTHER APPLICATIONS OF JUTE GEOTEXTILE IN ROAD SECTOR

JGT has been used in some other application areas in road sector. Following are some other applications of JGT in road sector:

1. Stabilization of earthen embankments for roads
2. Protection of banks of rivers
3. Bio-engineering support

7.1 Stabilization of Earthen Embankments for Roads

Stability of embankments implies stability of the soil-body as a whole, apart from the stability of the exposed slopes. Road embankments are subjected to moving loads which develop dynamic stresses within embankments also. Soils derive stability from their shear strength. The safe slope of an embankment depends on the shear strength of the fill. Non-cohesive granular soils possess high internal frictional resistance which helps develop increasing shear strength with the addition of load. This characteristic of non-cohesive soils allows construction of an embankment having stable and steeper angles than that of an embankment made with fine-grained cohesive fills. Soil in general hardly possesses any tensile strength. It behaves differently according to its composition, structure and other geotechnical properties. As a result, embankments constructed with soils prone to volumetric variations suffer failure in the shape of vertical subsidence, lateral dispersion, down-slope migration, rotational slides etc.

Slope-instability in earthen embankments is caused mainly due to saturation of the soil with entrapped moisture/water. Draining out of water from the sub-surface is the solution. Trench drains along the toe of the slope and also across it help drain out the surface run-off. Encapsulated drains are more effective when rubbles are encapsulated in JGT (usually non-woven JGT). Such JGT-encapsulated trench drains prevent ingress of erodable soil particles into the drain. The surface flow of water is unidirectional along slopes. Detachment and transportation of the upper layer of the soil on the slope due to rains/surface run-off are effectively tackled by open mesh JGT initially and by vegetation subsequently. The natural stability of the base soil remains unimpaired even after biodegradation of JGT unless there is an excessive geotechnical disturbance leading to instability of the slope and failure of the drainage system. Growth of vegetation on the slope adds stability to the slope naturally.

The use of JGT for reinforcing soil in the body of the embankment shall be based on the evaluation of improvement expected with regard to its stability because of such use. The improvement is a function not only of the fill-properties, but also of the JGT. Slopes can be effectively managed if the velocity of surface runoff can be reduced. Yarns of JGT placed normal to the direction of surface runoff act as mini check dams laid in series curbing the velocity of surface runoff and preventing migration of detached particles.

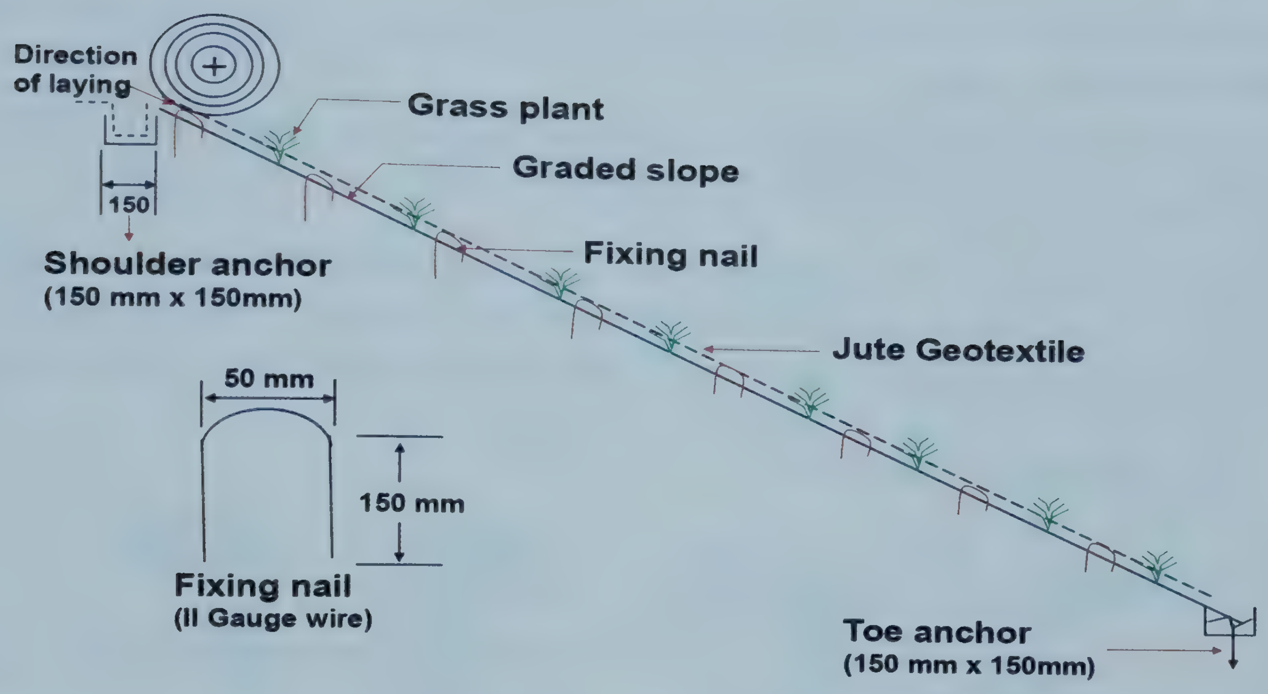


Fig. 14 Installation of Jute Geotextile

Sequence of laying JGT on slopes for rain water erosion control

1. The slope should be made free from undulations, soil slurry, mud and sharp projections and compacted with additional earth where necessary.
2. Broadcasting of seeds of appropriate vegetation (locally grown seeds).
3. Anchoring trenches should be excavated at the top and toe of the slope along the length of the embankment. Recommended dimensions of the trench (usually rectangular) are 300 mm deep and 250 mm wide.
4. The selected JGT should be rolled across the top trench and along the slope, downward, caring to see that it touches the soil surface at all points.
5. Overlaps should be minimum 100 mm at sides and 150 mm at ends. The end portion of JGT at the higher level on the slope should be placed over the start portion of JGT at a lower level. Side overlaps of a JGT piece should be placed over its next at a lower level. Side overlaps of JGT piece should be placed over its next piece on one side and under the next piece on the other.
6. The JGT should be fixed in position by steel staples usually of 11 gauge dia or by split bamboo pegs. Stapling should be done normally at an interval of 500 mm both in longitudinal and transverse directions. Special care should be taken to staple the JGT within the anchoring trenches both at the bottom and at the sides.
7. The anchoring trenches should be filled up with sand/brick-ballast/gravel etc. for keeping JGT in position. Care should be taken that the overlaps are not displaced during installation.
8. Care should be taken to ensure that the JGT is not damaged due to puncture, tear and other installation stresses.
9. Selection of type of vegetation is very important. Local experience should be the guide. Help of botanist, agronomist, local forest department in selection of species, timing of sowing/planting/broadcasting procedures, maintenance etc. are strongly advised.

10. In special circumstances, a second dose of seeds may be spread with sowing of locally available grass.
11. Installation should be completed preferably before the monsoon to take advantage of the rains for quick germination of seeds and growth of vegetation.

Special provisions can be made for draining out surface water run-off through a network of trench drains. High permittivity and separation are the deciding factors in trench drains. Non-woven JGT, which has a higher permittivity than the woven type and less costly, is recommended.

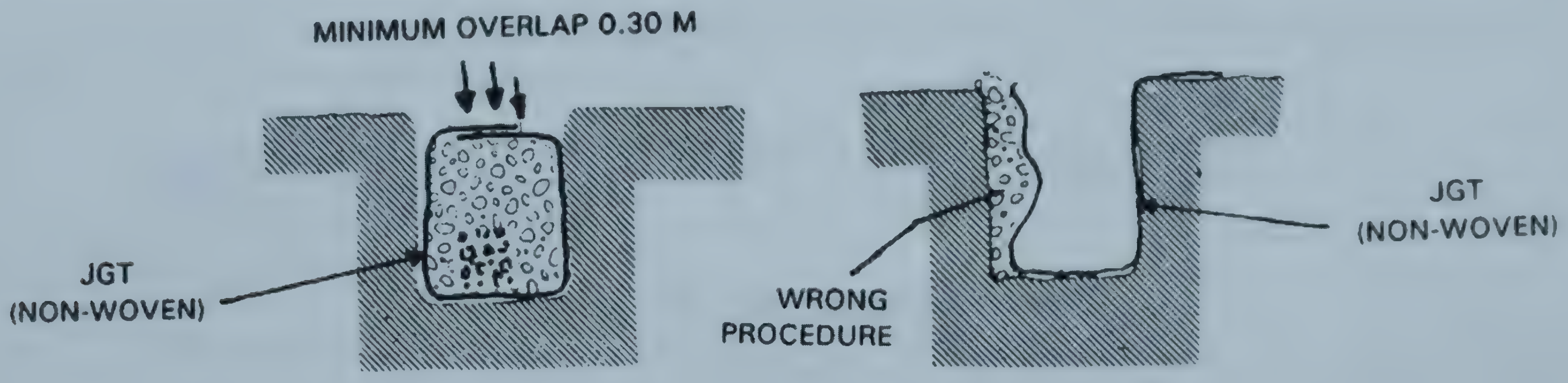


Fig. 15 Correct JGT-Laying in a Trench Drain

7.2 Protection of Banks of Rivers

JGT can also be used for protection of river banks. Following sequence of installation of JGT should be adopted:

1. The bank should first be cut to a stable slope preferably at the angle of internal friction of the bank soil. The surface shall be leveled and made free from angular projections, undulation, soil-slurry or mud.
2. Anchoring trench (usually rectangular) should be excavated (minimum 500 mm deep and 250 mm wide) at the top of the slope.
3. JGT should then be unrolled across the trench and along with slope from top to down side to the lowest water-level.
4. JGT should be stapled with U-shaped nails (usually 11 gauge) within the anchoring trench both at the sides and bottom at an interval of 300 mm along the length of the trench. There should be at least 2 staples both depth-wise and width wise in each cross-section.
5. JGT should be laid with the overlapping in the direction of water-flow. Care should always be taken to ensure that JGT does not suffer damage due to puncture, tear and installation stresses.
6. The recommended overlap is 150 mm (minimum). The overlapped portion should be stapled at an interval of 300 mm.
7. The anchoring trench should then be filled with stones/boulders for securing and protecting the JGT. Care should be taken to ensure that JGT touches the bank slope at all points (proper drapability).
8. Armour overlay of stone/boulder should then be placed on the JGT carefully and properly arranged. A thin layer of sand (25 mm) as a cushion on top of the JGT is recommended to avoid puncture of the fabric by granular armour.

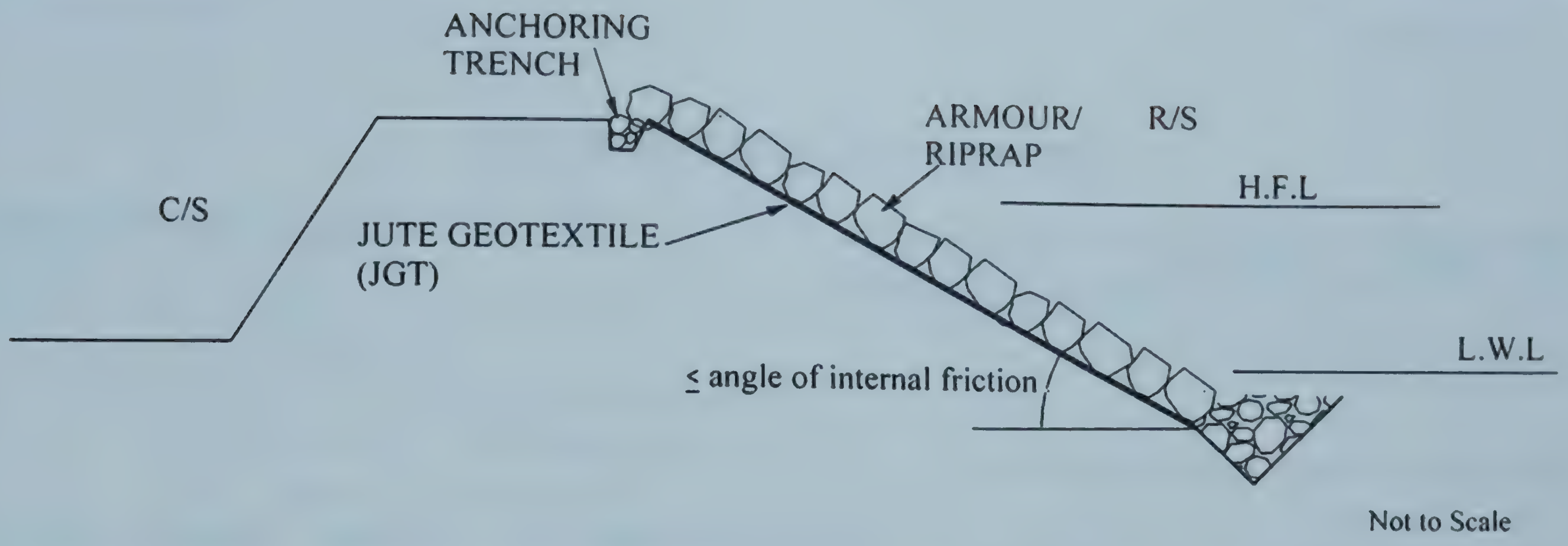


Fig. 16 Typical Cross Section of River Bank Protection Work

7.3 Bio Engineering Support

JGT facilitates, quickens and supports growth of vegetative cover on it. Once vegetation is grown, the function of JGT becomes redundant. Vegetation so grown, besides dissipating substantially, the kinetic energy of rain-drops, serves as a receptor of moisture with the help of leaves and stems. The wind-effects are also attenuated by vegetation. The velocity of surface run-off is also reduced by virtue of the surface rugosity (roughness) of the vegetation. The root system ensures soil-attachment and imparts strength to the soil-body. Soil-porosity and permeability are also improved, helping in control of erosion. And finally, vegetation provides a sustainable solution to the problems of erosion control. JGT, a natural product, fosters vegetation growth and paves the way for bio-engineering solution to the problem of soil-erosion.

The choice of species of vegetation depends on the nature and composition of soil which vary from place to place. Live sods of perennial turf-forming grass may be laid on embankment slopes, verges (earthen shoulders) and at other locations.

Proper preparation of the soil bed, application of manure and laying of JGT are basic pre-requisites for growth of a good vegetative cover.

To ensure quick growth of vegetation, selection of the right type of vegetation species is extremely important. Studies have revealed that JGT enhances micro-climatic conditions (like temperature, soil-moisture) and organic matter-levels in soil which are conducive to quick and sustainable growth of vegetation.

Annexure – 1

STIFFNESS OF JUTE GEOTEXTILE

Determination of elastic modulus of 724 gsm JGT (Double Warp plain weave) of weft and warp yarns has been evaluated as presented below:

Sample size = (10 X 20) cm

Direction of test = Warp Direction

Extension (%)	Strain (ε = mm/mm)	Stress (KPa)	Thickness (mm)	Width of sample (mm)	Load (kN)	Stiffness (K = F/ε = kN/m)
1.000	0.010	411.350	1.940	200.000	0.160	79.802
2.000	0.020	775.750	1.940	200.000	0.301	75.248
3.000	0.030	1228.400	1.940	200.000	0.477	79.437
4.000	0.040	1805.800	1.940	200.000	0.701	87.581
5.000	0.050	2551.950	1.940	200.000	0.990	99.016
12.650	0.127	15250.000	1.940	200.000	5.920	233.913

Direction of test = Weft Direction

Extension (%)	Strain (ε = mm/mm)	Stress (KPa)	Thickness (mm)	Width of sample (mm)	Load (kN)	Stiffness (K = F/ε = kN/m)
1.000	0.010	598.510	1.940	200.000	0.232	116.111
2.000	0.020	1426.140	1.940	200.000	0.553	138.336
3.000	0.030	2810.910	1.940	200.000	1.091	181.772
4.000	0.040	4799.720	1.940	200.000	1.862	232.786
5.000	0.050	7339.940	1.940	200.000	2.848	284.790

Annexure – 2

BILL OF QUANTITIES (BOQ) ITEM

Sl. No.	Description	Unit of Measurement	Quantity	Rate
1)	**Jute Geotextile**			
	"Supplying, testing and installation of 100 cm wide woven Jute Geo-textiles (JGT) 724 gm/sq.m possessing minimum tensile strength of 25 kN/m (MD and CD), with a porometry range of 100-400 micron and thickness 2 mm. Jute Fabric is to be laid with overlaps of 100 mm laterally and 300 mm longitudinally, duly secured to sub-grade by U shaped MS staples (11 gauge) at an interval of 750 mm or as per direction of the Engineer-in-charge. The rate is inclusive of all Govt. taxes, duties, cess as leviable, transportation from a reputed jute mill to the work site, in/c loading, unloading and storage of the material at site etc."	Sq.M.		

Annexure – 3

TENTATIVE LIST OF CENTERS WITH TESTING FACILITY

1. Indian Jute Industries' Research Association (IJIRA), Email: ijira@ijira.org, 17 Taratala Road, Kolkata - 700 088
2. Institute of Jute Technology, 35, Ballygunge Circular Road, Ballygunge, Kolkata, West Bengal 700 019, Email : ijt@cal1.vsnl.net.in
3. The Bombay Textile Research Association (BTRA), Lal Bahadur Shastri Marg, Ghatkopar(W), Mumbai - 400 086, Email : sakinaka@drbatras.com.
4. National Test House, Block-CP. Sect- V, Salt Lake City Kolkata - 700 091, Email: nthsal-wb@nic.in
5. Indian Institute of Technology (IIT) Delhi, Hauz Khas, New Delhi - 110 016, E-mail: webmaster@admin.iitd.ac.in
6. Ahmedabad Textile Industry's Research Association (ATIRA). P.O. Ambawadi Vistar, Ahmedabad - 380 015, Gujarat, Email: composites_testing@atira.in

(The Official amendments to this document would be published by the IRC in its periodical, 'Indian Highways' which shall be considered as effective and as part of the Code/Guidelines/Manual, etc. from the date specified therein)

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